

Urban Development and Sustainable Water Management of Southwest Cities

by

Richard Malloy

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Graduate Supervisory Committee:

John Brock, CoChair  
Chris Martin, CoChair  
Eric Thor

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## ABSTRACT

Water is the defining issue in determining the development and growth of human populations of the Southwest. The cities of Las Vegas, Phoenix, Tucson, Albuquerque, and El Paso have experienced rapid and exponential growth over the past 50 years. The outlook for having access to sustainable sources of water to support this growth is not promising due to water demand and supply deficits. Regional water projects have harnessed the Colorado and Rio Grande rivers to maximize the utility of the water for human consumption and environmental laws have been adopted to regulate the beneficial use of this water, but it still is not enough to create sustainable future for rapidly growing southwest cities. Future growth in these cities will depend on finding new sources of water and creative measures to maximize the utility of existing water resources.

The challenge for southwest cities is to establish policies, procedures, and projects that maximizes the use of water and promotes conservation from all areas of municipal users. All cities are faced with the same challenges, but have different options for how they prioritize their water resources. The principal means of sustainable water management include recovery, recharge, reuse, and increasing the efficiency of water delivery. Other strategies that have been adopted include harvesting of rainwater, building codes that promote efficient water use, tiered water rates, turf removal programs, residential water auditing, and native plant promotion.

Creating a sustainable future for the southwest will best be achieved by cities that adopt an integrated approach to managing their water resources including discouraging discretionary uses of water, adoption of building and construction codes for master plans, industrial plants, and residential construction. Additionally, a robust plan for education of the public is essential to create a culture of conservation from a very young age.

## DEDICATION

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## PREFACE

The focus of this research project is to provide a broad view of common concerns facing southwest cities in the areas of development and the management of water resources for Las Vegas, Phoenix, Tucson, Albuquerque, and El Paso. As the areas major rivers are experiencing declining annual flows from climatic and environmental conditions, the southwest continues to develop and urbanize. Each of these cities has unique characteristics that have allowed them to become a major urban center in the southwest, but the fundamental need for water to sustain these cities will present real opportunities to develop creative planning to make wise use of their limited supplies of water.

In this study, the questions of how these southwest cities developed over time and what they are doing to try to manage sustainable water management policies, practices, and projects are addressed. Through the process of examining these urban centers on a comparative basis, a more comprehensive view can be gleaned from the efforts made to date in water management and what might be future areas of concern for future development of the region. Additionally, this study will provide background on critical environmental and social concerns for development in the southwest.

## 1. INTRODUCTION

The Southwest cities of Las Vegas, Phoenix, Tucson, Albuquerque, and El Paso are the largest centers of urban population in the desert southwest and have been among the fastest growing urban areas in the country in recent decades. The recent economic downturn in the United States starting in 2008 hit the Southwest region extremely hard, forcing state and local agencies to make deep and painful cuts due to the dramatic fall in revenues to fund government operations. Today, these cities are digging out from some of the highest home foreclosure and unemployment rates in the country. This pause in the pace of urban development of these cities exposed the fault in the economies of southwest cities- an overreliance on growth and development activities for sustaining the economy. Additionally, the American West is facing some of the most challenging decisions regarding water management and use as climatic conditions have depleted the regional aquifers, reservoirs, and underground water supplies. The lessons learned from this and past cycles of boom and bust can provide lessons to put forth a new vision that will sustain the region with solutions that better serve the residents of southwestern desert cities, if the municipal leaders and public act prudently with policies and programs that will promote responsible development and sound water management.

This thesis will describe the process of urbanization in the Southwestern cities of El Paso, Albuquerque, Las Vegas, Phoenix, and Tucson from the natural environment to the current metropolitan settings and what measures these cities

have adopted for sustainable water management for future growth and development. Much like a living organism, without adequate water cities will not grow to their full potential. In summary, this thesis will provide a snapshot of these important urban centers in their founding, development, and efforts to balance growth, water security, and conservation.

## 2. RESEARCH METHOD

This thesis utilized the case study method to present the findings of this analysis of southwest cities and their struggles to balance development and sustained water supplies for the future. A multiple case study approach was chosen to compare several comparable cities in their efforts to deal with development and growth at the same study, using the municipality as the unit of analysis (Yin 2009). This approach provided the most salient method of examining multiple cities in different geographic and climatic regions, and shaped by different regional and local administrative authorities. To conduct this analysis, historical data was obtained from the U.S. Census Bureau on population, land area, and economic development. Information on sustainable water management practices was obtained from the municipal documents and web sites. The discussion and conclusion will compare and contrast the most notable finding of this research study.

## 3. CASE STUDY

### **3.1 Southwest City Development**

While the European settlers were busy building up the Eastern and Midwestern urban communities of the United States, the desert Southwest was largely an uninhabited region. This rugged desert landscape has been molded by the natural hydrologic and climatic cycles, which always seems restore the land to a state created by the thousands of years of navigating a delicate balance of hydrologic processes and climate. Over the last century, this fragile landscape has turned into some of the most intensely developed areas in the United States. Southwest urban centers of El Paso, Albuquerque, Las Vegas, Phoenix, and Tucson have evolved over time to balance the struggles between life and death of the biotic communities. This rapid pace of development brings to mind a concern about the process of urbanization, which often irreversibly alters the complexity of the natural setting.

The southwest desert region was once a highly desirable place for people to live with health problems or those seeking a place with a closer connection to nature. By the turn of the 20<sup>th</sup> Century, the quality of life of Southwest cities was once the highest marketing aspect of the region for health seekers. Today, people move to the Southwest for jobs, reasonable land values and affordable housing among other factors. Urban sprawl has altered the environment that once featured clean, dry desert air to one that has deteriorated to point that the quality of the air can be detrimental for people with poor health to live without discomfort in the urban centers.

Growth and development in the Southwest activities in the Southwest are expanding the land area of urban cities from the conversion of native desert or agricultural land to urban developments. Urbanization is an irreversible process of transformation from the natural to the built environment. In his book entitled *Urban Society: An Ecological Approach*, Hawkey states that this change is “*movement from the simple, highly localized unit to the complex and territorially extended system is a growth process. We use the term urbanization to refer to that process*”(Hawley 1981). Southwest cities are now rapidly expanding into their urbanization process faster than most people could have previously imagined. While some the older, industrialized cities in the East and Midwest are experiencing decline in population and vitality, Sunbelt cities are blessed with new founded prosperity and development. Growth is not always achieved from the most noble and ecologically sound reasons. Speculation and profit have been drivers of western land development for many decades. Some cities have actively taken on the community’s role in balancing environmental protection and economic development; other areas are still at the mercy of speculative interests for sustaining the community. Unfortunately, once the natural landscape of the desert has been adversely transformed through human intervention, the result of this intervention can have a long-term impact on future development potential for this landscape.

### **3.1.1 Early History**

The earliest settlers of the region were the *Hohokum* Native Americans that settled along the Salt and Gila Rivers in modern day Arizona and developed extensive

irrigation canals and aqueducts. The Hohokum proved to be remarkable engineers to manage the land for crop production. These sedentary tribes farmed the river valleys with crops of corn and squash and lived in simple mud brick houses. To the north in high desert country, the *Anazasi* tribes inhabited the dry desert mesas with their cliff dwellings and pit houses. The Anazasi were largely hunting and gathering tribes that made unique pottery and jewelry designs. The ancient tribes appeared to vanish from the region about 1150 AD leaving no trace for the tribes that followed into the region. To this day modern anthropologists can only theorize as to the demise of the ancient cultures with ideas such as ecological disasters or disease, but without conclusive evidence.

A few early accounts from explorers were documented by explorers and in the Southwest; Juan de Oñate made famous the *Camino Real* or Royal road, a highway that linked the Southwestern to the interior of Mexico (Figure 1). Oñate was in search of resources to enrich the Spanish Crown from the newly founded territories. His relationship with the native cultures was tolerant, but sometimes barbaric. To the west, Father Eusebio Francisco laboriously established the Jesuit missionaries of Tubac and San Xavier del Bac in Southern Arizona and Mexico. Kino's missions were largely successful in attracting the natives to support the agrarian, Christian-based community, some of which are still in use today.



Figure 1 Camino Real Map

Source: U.S. Parks Service

Until the Mexican American war in 1846, the desert Southwest was under the control of New Spain ruled from the European continent. The region was sparsely settled with few small towns of any size. The population was largely Hispanic farmers and ranchers that homesteaded pastoral lands or farms. Small settlements were established periodically along the major rivers of the region where a more permanent source of water could support a growing community. A large portion of the Southwest was added to the United States after the controversial Mexican American War through the Treaty of Guadalupe Hidalgo in 1848. Additional lands were acquired from Mexico through the Gadsden Purchase in 1853, which added lands south of the Gila River to the border with Mexico and is the current

international boundary. To the east, the State of Texas was formed by cessation from Mexico and annexation in 1845. The current state boundaries include some areas claimed by Texas in the years after joining the Union (Figure 2).

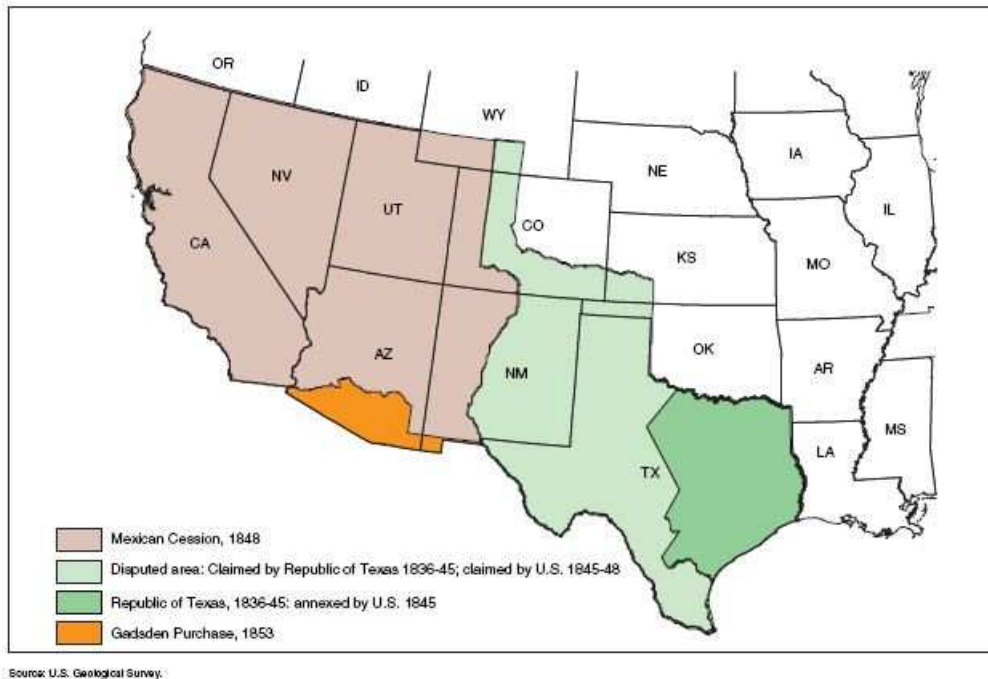


Figure 2 U.S. Land Acquisitions

Source: U.S. Geological Survey

### 3.1.2 Original Settlements

The regional settlements of the major Southwestern cities were strategically located near major rivers in relatively flat, defensible landscapes. By the time European settlers were passing through the region, the major concern was protecting the community from periodic attacks. Apache and Comanche tribes carried out regular raids on many who passed through the region. Not until the



surrender of Geronimo, the infamous Apache warrior in Southern Arizona, was the threat of hostilities considered close to a manageable for the local population. As a result most of the settlements remained close in proximity and established outposts for protection against the Indian threat.

## **El Paso**

In 1598 Juan de Onate declared El Paso del Norte in the name of New Spain. The pass was a stop along the *Camino Real* (Royal Road) that linked with the interior of Mexico. Just south of El Paso del Norte Father Garcia de San Francisco established a mission in what is now the City of Juarez, Mexico. This rapidly developing city was situated right on the US/Mexican border in the Chihuahuan desert. The town became a major stop on the Butterfield Overland mail coach route. El Paso quickly developed a reputation as a lawless center where gunslingers and rustlers had their way about town. This fertile valley was the home of pastures, farms and vineyards along the Rio Grande River.

During the period from 1852-1868 the Rio Grande river experienced severe and violent floods that shifted the course of the river to the south. This diversion of the river added several hundred acres of land to the United States south of the urban center of El Paso, now considered valuable developable land. Mexico made repeated claims to the Chamizal lands in dispute, citing that previous treaties with the U.S. define the center of the Rio Grande River at the time of the treaty as the international boundary. Both countries agreed to arbitration in 1910 that resulted

in a proposal to return the lands to the historic boundaries and transfer of lands back to Mexico. The U.S. refused to accept this settlement and continued to ignore Mexico's pleas to settle the dispute. The issue was finally resolved when John Kennedy agreed to settle the dispute in accord with the 1911 arbitration proposal, and was eventually signed by President Johnson in 1967. Both countries shared the cost of channelization of the Rio Grande and the exchange of the lands to Mexico (Galdys and Liss 2002) The *Chamizal Dispute* is an important milestone in Southwestern history in urbanized settings where the issue of land was an emotional, valuable and an object of national pride, more on the part of the Mexican perspective, but smoothed the path of diplomatic relations with Mexico who was still angry about the U.S. land grab of northern Mexico territories after the Mexican American war.

### **Albuquerque**

In 1540 the Spanish explorer Francisco Vasquez de Coronado traveled through the New Mexico region in search of the Seven Cities of Cibola. After spending the winter camped along the Rio Grande River, Coronado proceeded north to establish the town of Santa Fe in 1610. The Spanish sought to control the Pueblo Indians and a strong rebellion ensued by the 1580's that drove the Spanish to the south for over 10 years until the area was recaptured. The villa of Albuquerque, named after the Duke of Spain, was founded in 1706 and was the next major westward stop along the Camino Real from El Paso del Norte. By 1880 the railroad

had entered the territory, and in 1885 the town of Albuquerque was founded. In 1889 the University of New Mexico opened its doors as the new higher education center of the region. The town remained part of the New Mexico territory until 1912 when New Mexico became the 47<sup>th</sup> State in the Union.

### **Las Vegas**

The dusty town of Las Vegas was named after the Spanish term that means “the meadows”. The site was one of the few artesian springs that emerged from the parched landscape. The Mormon Church had grand plans for building a string of settlements from Salt Lake City to the Pacific Ocean. In 1855 a fort was constructed by the Mormons to build farming and mining communities, but was left abandoned by 1857. Las Vegas had been part of territorial New Mexico when the Mormons built their fort in 1855, but the western segment of the territory became part of Arizona in 1863, when the new state of Nevada was created, Las Vegas was part of Mojave County, Arizona (Land and Land 2002).

Las Vegas had a bad reputation from some of the illicit activities in the settlement from whiskey running, prostitution, and cattle rustling. The region was promoted and profited by the flamboyant and controversial Senator William Clark, a developer that had a questionable reputation. The city was founded in 1905 after a land auction of 110 acres creating the Las Vegas town site, and was governed as part of Lincoln County until 1909 when it served as the seat of the newly created Clark County. The city benefited greatly from state legislation that legalized

gambling in 1931 and the signing of the Boulder Canyon Project Act in the same year by Calvin Coolidge. This act began the largest, most ambitious government construction project; the Hoover Dam.

## **Phoenix**

While the Spanish explorers paid attention to other Southwestern regions, the Salt River Valley was largely undisturbed throughout the colonial period. In 1865 the United States Army established Fort McDowell about 20 miles north of the Salt River to defend the area from hostile Indian attacks. About the same time, a former soldier John William (Jack) Swilling saw great potential in rekindling the old Hohokum canal system to irrigate the valley. Swilling, aware of the potential for revitalizing the land, called the settlement Phoenix, after the legendary bird that rose from the ashes with new life. In April of 1870 a 320 acre parcel was issued to the town site of Phoenix. In 1881 the town site was incorporated into a city and John T. Alsap served as the first mayor of Phoenix. The completion of the Roosevelt Dam and the Arizona and Grand canals fueled the interest in settlement of the Salt River valley, which allowed settlers to irrigate large tracts of land once limited by the availability of reliable sources of water for agriculture and development (VanderMeer 2010).

## **Tucson**

Tucson was founded by Hugh O'Connor in 1775 under the direction of the Spanish Crown to located and establishes an outpost along the Santa Cruz River.

O'Connor selected a site on the east side of the Santa Cruz River to establish Presidio San Augustin. Tucson was a name taken from the Indian designation of a local landmark spring located at the base of the modern day Sentinel Peak. Tucson was added to the United States in the territory that was acquired in the Gadsden Purchase in 1854. Tucson was the territorial capital from 1867-1877 when it was relocated to Prescott. Over the next decade the Tucson delegation worked feverishly to regain the territorial capital each time the legislature met. In 1885 Tucson was awarded a \$25,000 appropriation to found the University of Arizona. However, the local residents were shocked that they were awarded the university rather than the territorial capital as a prize and almost forfeited the award until a benefactor stepped forward with the required land contribution for the new university (Luckingham 1982).

<b>Desert City Characteristics</b>					
<b>Feature</b>	<b>El Paso</b>	<b>Albuquerque</b>	<b>Las Vegas</b>	<b>Phoenix</b>	<b>Tucson</b>
Year City Founded	1873	1891	1905	1881	1885
County	El Paso	Bernalillo	Clark	Maricopa	Pima
Elevation	3,740 ft.	5,312 ft.	2,001 ft.	1,086 ft.	2,389 ft.
River	Rio Grande	Rio Grande	Virgin	Salt	Santa Cruz
Annual Rainfall	9.69 in.	9.43 in.	4.19 in.	8.03 in.	11.56 in.
Average Temperatures <sup>1</sup> H/L	77.4/51.6	68.7/45.4	80.1/58.7	86.6/63.4	83.1/63.
Nearby Mountain Range	Franklin	Sandia	Spring	South Mountain	Santa Catalina
Desert Community	Chihuahuan	Chihuahuan	Mojave	Sonoran	Sonoran

<sup>1</sup> Average annual temperature and precipitation based on the average of NOAA climate data from 1981-2010

## Table 1 Characteristics of Desert Cities

Source: (Wikipedia 2013)

### 3.2 Southwest Water Engineering and Development

The desert Southwest is an area defined by the scarcity and unpredictability of water supply. The settlements of Southwest cities were established on what was then flowing rivers; although maybe not in large in size, but provided adequate supply of water for the small population of these areas at that time. At first, these young cities were able to provide water by primitive means, by windmill pumps, aqueducts or even water delivery services by a water wagon. All of these desert cities were sited near known sources of perennial water in streams, rivers and artesian wells. As the population began to grow, the cities began to recognize the need for a more sustained long term solution to supply water for the growing cities. The future of these desert communities were tied to securing a permanent, reliable source of water.

In the first decade of the 20<sup>th</sup> Century the Federal government began serious consideration of engaging in water reclamation projects to address the problems presented by the periods of drought and flooding that plagued the major rivers of the region. Major flooding of the Salt River in the 1890's and later the diversion of the Colorado River began flooding the Salton Basin in 1905 to form an inland sea

before the river course was corrected. At the same time, frequent and unpredictable changes in the other major rivers such as the Salt, Verde, Santa Cruz, Gila, and Rio Grande presented a concern for the development and public safety for area leaders to address (Webb and Leake 2013). After careful evaluation, the Bureau of Reclamation chose the Salt River Dam project to be the first major project to be undertaken by the Federal government to address concerns about western water issues.

The Salt River Dam was the first water reclamation project initiated by the Federal government in 1902 after successful attempts to secure funding by Benjamin Fowler and George Maxwell in Washington for the passage of the Newlands Act to fund the construction of the Roosevelt Dam. In 1904 The Salt River Valley Water Users Association was formed to negotiate a contract to repay the Federal government for the construction of the dam. The dam was dedicated by Theodore Roosevelt on March 18, 1911 with much fanfare (Figure 3). The Roosevelt Dam had an immediate economic and social impact for the Phoenix area. An extensive canal system was soon constructed that carried water to areas that were previously desolate and farms and ranches were allowed to prosper along the path of the canals. The success of the Roosevelt dam fueled ideas for bolder and far reaching water projects in the west. The idea that modern engineering could harness the west created great excitement for investment and growth possibilities, particularly with the Eastern and Midwestern establishments.



Figure 3 Roosevelt Dam under construction

Source: Salt River Project

In 1928 Congress passed the Boulder Canyon Project Act that authorized the construction of the Boulder Canyon (later renamed to Hoover Dam) project. Before construction, the Federal government reached an agreement with the states for the division of river allotments. The river was separated into upper and lower divisions. Each division would share the water proportionately with considerations for future settlements with Mexico. The Boulder Canyon project was the largest public works project ever undertaken by the Federal government (Figure 4). This project provided thousands of jobs for willing workers, many of whom migrated



from areas deeply affected by the height of the depression-era economy, and served as a catalyst for growth of the otherwise desolate area around Las Vegas, Nevada.



Figure 4 Hoover Dam

Source: U.S. Bureau of Reclamation

New Mexico and West Texas had a similar dilemma with the Rio Grande River. After contentious debate among delegates from Texas, New Mexico and Mexico, and the benefactors of the dam project, it was decided that the site at Elephant Butte Lake was the best location to build this reclamation project. In 1906 the United States signed a treaty with Mexico for the equitable distribution of Rio Grande water through the delivery of water to the *Acequia madre* at Juarez of 60,000 acre feet a year. As with the Roosevelt Dam project, a water users group was formed to reimburse the Federal government with the dam construction costs over time. The dam was complete in 1916 for a cost of \$5.2 million dollars. A hydroelectric plant was added later in 1937 to provide electric power to the region (Figure 5).



Figure 5 Elephant Butte Dam

Source: U.S. Bureau of Reclamation

<b>Southwest Dam Data</b>			
<b>Fact</b>	<b>Elephant Butte Dam</b>	<b>Hoover Dam</b>	<b>Roosevelt Dam</b>
Constructed	1912-1916	1931-1936	1903-1911
River System	Rio Grande	Colorado	Salt
Storage Capacity	2,109,423 ac. ft.	28,537,000	2,910,200
Height	301 ft.	726.4 ft.	356 ft.
Crest Length	1,674 ft.	1,244 ft.	723 ft.
Crest Elevation	4,414 ft.	1,232 ft.	2, 218 ft.
Concrete Used	629, 500 cu. yds	3,250,000 cu. yds.	606,000 cu. yds.
Drainage Area	28, 900 sq. mls.	167,800 sq. mls.	5,830 sq. mls.

Table 2 Dams of the Southwest

Source: U.S. Bureau of Reclamation

In spite of the successes of the Roosevelt, Elephant Butte, and Hoover Dams, Central Arizona was left without a permanent solution water solution. A dam project was proposed in Tucson at Sabino Canyon in 1936, and received widespread support until the Army corps of Engineers put the local contribution for the dam construction at \$500,000. The political leaders at this time were not able to muster the financial backing within the community and the idea of banking water in Southern Arizona was tabled. Inaction on dealing with the larger water problem in Tucson left the region with no choice other than to rely on groundwater pumping for the foreseeable future. Some relief was on the way, however, with a long awaited construction of the Central Arizona Project (CAP), a multi-billion dollar Federal

project that would divert Colorado River water into Central and Southern Arizona. CAP took many decades to become a completed project (Figure 6).



Figure 6 Central Arizona Project Canal

Source: U.S. Bureau of Reclamation

The CAP was originally proposed in 1947, but was not authorized until 1968 because of agreements on the merits of this project with other regional stakeholders. Political wrangling over appropriation of funds ensued in the years following the authorization of the CAP. The debate over the CAP forced the enactment of the broad-sweeping Arizona Groundwater Act in 1980. This act established active management areas in Arizona and provided guidelines for water conservation and recharged targets for replenishing groundwater depletion within the management areas.

In spite of all the engineering efforts to capture and store river water, the Colorado and Rio Grande rivers have long been over allocated in water use between the Colorado River basin states and Mexico. The rapid population growth of the southwest has increased the need for water resources to support agriculture, industry and domestic uses across the region. The southwest region is experiencing drought conditions that are diminishing the excess water in storage in the reservoirs creating the immanent need to establish drought management planning for all users along the river. The Executive Summary of a 2012 study of supply and demand for future water needs for the next 50 years concludes “[w]ithout future water management actions, a wide range of future imbalances are plausible primarily due to the uncertainty of future water supplies” (U.S. Bureau of Reclamation 2012). Figure 7 highlights the historical supply and demand for Colorado River water showing a steady increase in demand for water and cyclical deficits of supply, particularly since 1980. Additionally, the Rio Grande River is experiencing similar trends in available water. In July of 2013, the U.S. Bureau of Reclamation halted its summer irrigation deliveries to unprecedented low storage levels in the Elephant Butte Lake of 3% of its capacity (Alba Soular 2013). The unpredictability of the supply of water to support development in the southwest poses a serious risk to future plans for southwest metropolitan areas.

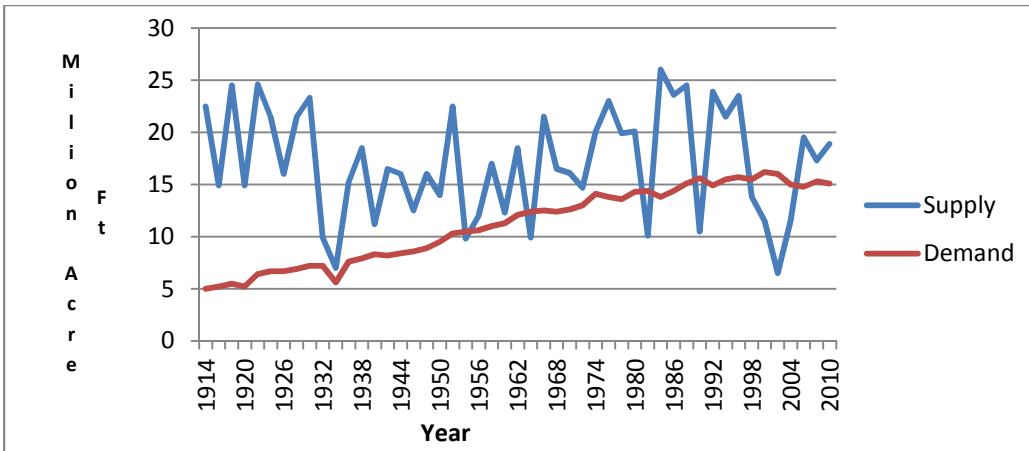


Figure 7 Historical Annual Colorado River Basin Supply and Use

Source: (U.S. Bureau of Reclamation 2012)

### 3.3 Economic Development and Water

Southwest cities early on attracted people because of the warm climate and wide open spaces. The completion of the Roosevelt Dam in 1911 opened a floodgate of interest from people interested in farming and ranching along the newly constructed canal system. Phoenix, Tucson, Albuquerque and El Paso were actively competing with each other for eastern clients seeking a cure for tuberculosis. The dry desert climate was promoted by many to help those people afflicted by this devastating illness. Many, in fact, were cured through their convalescence in the desert. In El Paso Drs. Charles Hendricks and Albert Baldwin established large successful sanatoriums to treat tuberculosis patients. In Phoenix, Hotel Adams was considered one of the finest hotels in the region, located at the corner of Central Avenue and Adams Street in the downtown district. Other stores began to prosper in the newly thriving urban centers, such as the M. Goldwater and Brothers a

successful Jewish merchant relative of Barry Goldwater, a former Arizona Senator (VanderMeer 2010).

Military bases played a large role in the development of Southwest cities. At first, the bases served as a means of protection against the savage Indian raids. As the area matured, the military bases had become a valuable part of the economic base of the city by providing employment, steady income for area suppliers and were often responsible for helping to improve local infrastructure that provided service to the base. Ft. Bliss in El Paso was established in 1849 and continues to function as an active military base today. Ft. Lowell in Tucson was an active fort, but later was abandoned after the Civil War ended. Ft. McDowell in Phoenix played a key role in providing protection for the settlements along the Salt River valley. During WWII Davis Monthan Air Force Base in Tucson, Nellis Air Force Base in Las Vegas, Luke Air Force Base in Phoenix and the Sandia Complex in New Mexico added economically to the local economies by adding jobs and large financial impact to the locality. A 2002 report estimated that the payroll and expenditures from military operations in Arizona contribute over \$1.5 billion dollars to the state economy and employs over 41,000 people (MaGuire Company 2002).

Copper mining was a large economic interest from Southern Arizona to El Paso. The Florilla mining Company opened in El Paso in 1899, followed by the El Paso Tin and Smelting Company in 1909. Other mining operations developed as new rail lines were able haul the heavy ore to smelting facilities In El Paso; the Farrah clothing manufacturing company opened a plant that employed more than 5,000

garment workers. Cotton was a crop of choice for Southwest farmers in dry land or irrigated croplands. Desert lands were used to graze cattle where no other crop would survive.

In other parts of the Southwest low land costs and relative cheap labor costs were drawing businesses from across the country. By the 1950's Phoenix had become the most aggressive seeker of corporate firms by creating a favorable business climate for large defense and aerospace firm. Phoenix's geographic location about midpoint between the major manufacturing centers of Chicago and Southern California made the city attractive to cost conscious firms. The first major player in the Phoenix market was Motorola. By 1960 the corporation had three major plants in the valley with over 5,000 employees (Luckingham 1989). Phoenix boosters had a well-coordinated team of leaders that actively sought out clean, high technology companies over all other Southwest cities. The result of the booster efforts created a diverse industry and technology manufacturing to the city that formed a diverse economy that was unparalleled in the region. Table 3 and 4 demonstrate the difference in manufacturing and wholesale sales in region. It is clear that Phoenix outpaces all other cities in scale of goods produced.

### **3.4 Spatial and Demographic Development**

After World War II the growth rate of Southwest cities accelerated rapidly. The low cost of land, favorable business climate and warm weather were factors that drew people to settle in these Sunbelt cities. One of the catalysts for the



suburban postwar boom was a Phoenix developer named Del Webb. His visionary low cost developments provided affordable houses to people in search of good clean housing stock in the desert. A Webb legendary development in Sun City to the west of Phoenix was a monumental success in marketing his active retirement community. His developments sold as quickly as they could be built (Finnerty 1991). Low density suburban development was the driving force of most Southwest cities. New development began to spring up on the fringes of the cities. The race to develop new land on the edge of the urban center continued to expand the urban limits of cities, sometimes with adverse consequences for the existing residents.

Manufacturing (NAICS 31-33)										
City	1997		1987		1977		1967		2007	
	Establishments	Value added (millions)	Establishments	Value Added (millions)	Establishments	Value Added (millions)	Establishments	Value Added (millions)	Value Added (millions)	Establishments
El Paso	599	3,115.9	507	1,377.8	386	689.9	244	184.9	579	2,897.9
Albuquerque	592	D	499	673.6	483	288.7	212	69.8	562	1,507.2
Las Vegas	274	273.0	159	138.5	150	D	81	19.6	225	275.6
Phoenix	1,706	10,283.8	1,559	4,665.3	1,284	1,923.4	790	517.3	1,637	6007.5
Tucson	520	1,767.5	497	1,745.3	303	287.1	204	47.8	484	1,234.0

Table 3 Manufacturing Outputs of Southwest Cities

Source: U.S. Census Bureau

Wholesale Trade (NAICS 42)										
City	1997		1987		1977		1967		2007	
	Establishments	Sales (millions)	Establishments	Sales (millions)	Establishments	Sales (millions)	Establishments	Sales (millions)	Establishments	Sales (millions)
El Paso	950	5,954.5	876	2,629.3	650	1,271	489	532	2,961	4,462.8
Albuquerque	919	3,630.1	1,031	2,717	714	1,325	484	435	866	4,844.1
Las Vegas	500	2,208.8	349	1,172.3	285	425	177	138	449	1,709.5
Phoenix	2,447	21,996.9	2,412	12,583.2	1,658	4,830	1,144	1,420	2,332	29,631
Tucson	615	1,801.0	682	1,270	464	674	324	199	641	9,596.5

Table 4 Wholesale Trade of Southwest Cities

Source: U.S. Census Bureau

Land annexation is the primary means for cities to acquire lands to expand urban boundaries. Annexation in Arizona only requires 51% of the landowners to be annexed to agree to the measures. Phoenix adopted aggressive annexation planning strategies starting in the 1960s, which led to a rapid expansion of the urbanized boundaries in all directions (VanderMeer 2010). In New Mexico, annexation can be carried out by petition, arbitration boards or through the Roswell Law, which allows any city to annex an area by resolution if the area borders the city on two sides. Albuquerque's aggressive use of annexation measure to acquire land prompted the state legislature to pass a law to halt any future annexation by the city unless it had 100% approval by the landowners to be annexed (Logan 1995). Figure 8 and 9 show the rapid and exponential growth in land area and population of southwest cities, particularly after the 1960s. Alternatives to low-density sprawl have been proposed by various groups, including growth boundaries and targeted incentives for development and transportation alternatives, but the free market forces won out in the Southwest to comprehensive policies on growth.

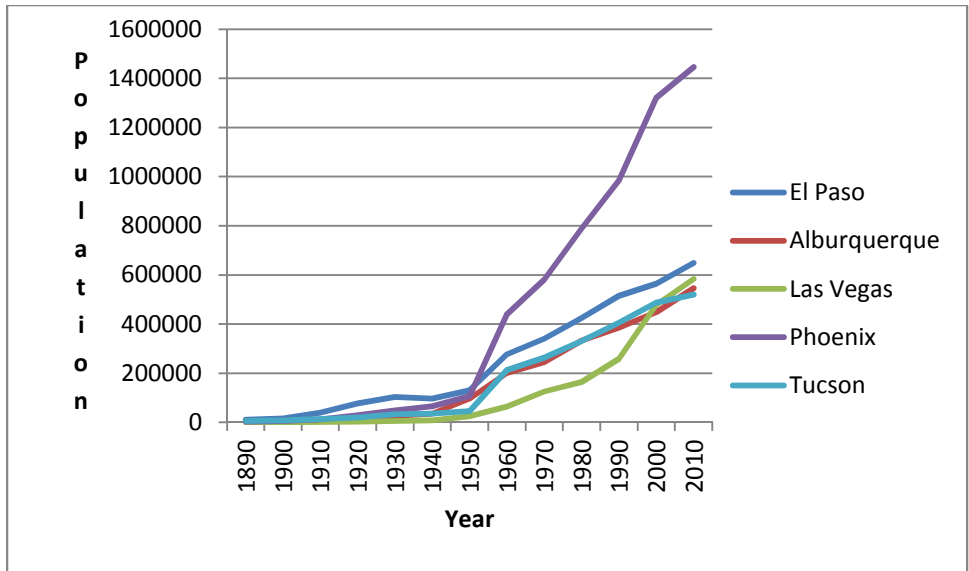


Figure 8 Population Growth of Southwest Cities (square miles)

Source: U.S. Census Bureau

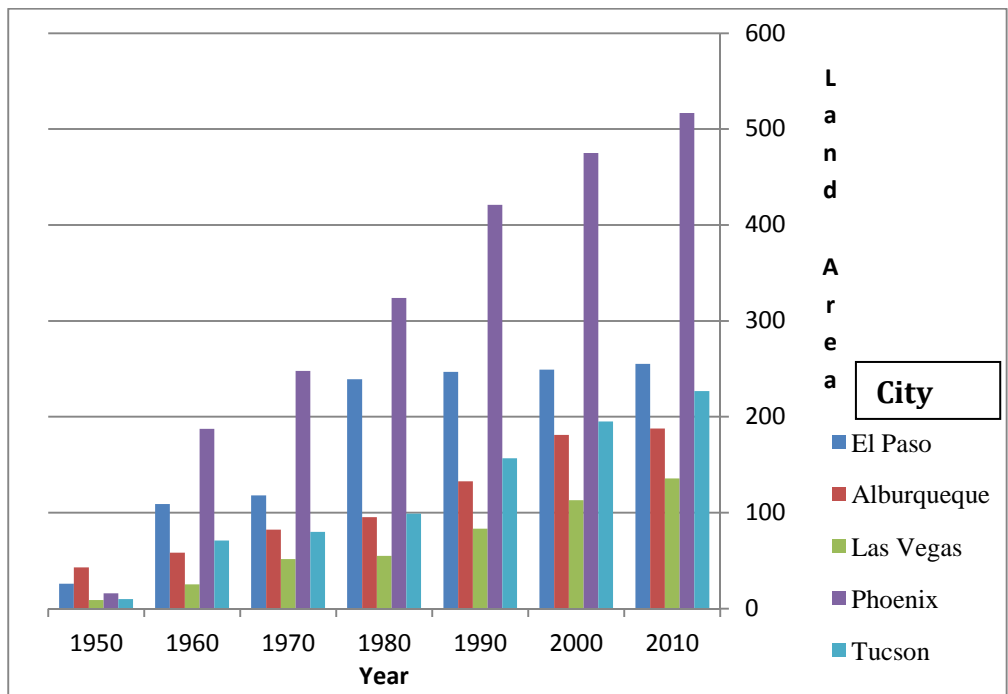


Figure 9 Southwest City Land Area (square miles)

Source: U.S. Census Bureau

Phoenix continued an aggressive annexation policy to expand the boundaries of the city. Development continued at such a rapid pace it neglected essential areas deep within the urban core of the city. Even by the 1950's, a pattern of decline in the Central Business District was observed. As urban development pushed to the fringe, parcels of urban land remained vacant in the city center. Recent efforts by the City of Phoenix to work with Arizona State University to develop a Capital Center university in the downtown area and the presence of T-gen- a biotechnology consortium, the construction of a light rail system and other development projects other have significantly revitalized the urban core and will help ensure this city will be able to sustain itself for decades to come.

### **3.6 Development and Water Policies for the Southwest**

The development of the West by the turn of the 20<sup>th</sup> century raised several concerns from the Western States on how to ensure fair and equitable use of the rivers. The population growth in California in particular had several of the region's leaders concerned that this growth could lead to disproportionate use by some states. The proposed construction of a dam near Boulder Canyon prompted the need to establish guidelines for how the Colorado River water would be shared amongst the states. In 1922, the six Colorado Basin states met to sign the Colorado River Compact, which divided the river into two water management groups- the upper including Wyoming, Utah, Colorado and New Mexico and Lower Basin that included Arizona, Nevada, and California. Arizona refused to sign the compact, citing fears of

California's overreach in the collective management of the water portfolio. Each basin was allotted 7.5 million acre feet of water. The division of the Lower Basin allocated 4.4 million acre feet (MAF) to California, 2.8 MAF to Arizona, and 0.3 MAF to Nevada. Arizona eventually signed onto the compact in 1944, but remained grossly unhappy about this arrangement.

The Colorado River compact, which was formed with Western states in the 1920's, has been under scrutiny as a shift in demographics has dramatically changed over the last 80 years. The state of Nevada, at the time of the compact, was a desolate place with little hope of sustained development. In token, a paltry allotment of 300,000 acre feet a year was awarded to the state, a small amount in comparison to Arizona's and California's share (U.S. Bureau of Reclamation 2008). Growth of Southwest cities has added increased burdens on the infrastructure to support the growing urban populations. Despite the major water projects such as dams and canals, these cities began to experience increased demands for water, causing the rapidly growing municipalities to search for new solutions to managing water resources in the urban areas.

Arizona, unhappy with negotiations on water use on the Colorado River, took its case to the Supreme Court resulting in the 1963 decision *In Arizona v California*. This case clarified the division of future surpluses of water on the river, as well as some disputes over water rights. In addition, the outcome of this case propelled the Central Arizona Project (CAP) to be approved by congress in 1968. CAP was one of the largest aqueduct projects in the United States. The aqueduct was built to divert

water from the Colorado River through central Arizona with potential extensions to New Mexico. In response to Federal ultimatum to reduce its groundwater use, Arizona adopted a stringent water management policies in 1980 entitled the Arizona Groundwater Management Act (AGWA) to be administered by the Arizona Department of Water Resources (ADWR). The act created five 'active management' areas (AMA) that included all of the urbanized areas in the state including Phoenix, Tucson, Pinal, Prescott, and Santa Cruz (Figure 10). All development projects within the AMAs are required to demonstrate 100 years supply of water is available to support this development. Developers protested the requirements of the AGMA's ability to limit development outside municipal water provider's service area. ADWR back peddled on this regulation by establishing the Central Arizona Groundwater Replenishment District (CAGRDR). This new entity was set up to legal documents to ensure that an equal amount of water that was withdrawn is replenished in the AMA. There is no requirement that the water be returned to the same aquifer or within close proximity to the place it was withdrawn. Currently, CAGRDR serves as the water bank on paper for disconnected development outside the urbanized areas. The CAGRDR is at the same time, a step in the right direction for preventing overdraft of groundwater and a measure that has ecological flaws in the manner of establishing "place-based" management of water resources in these areas.

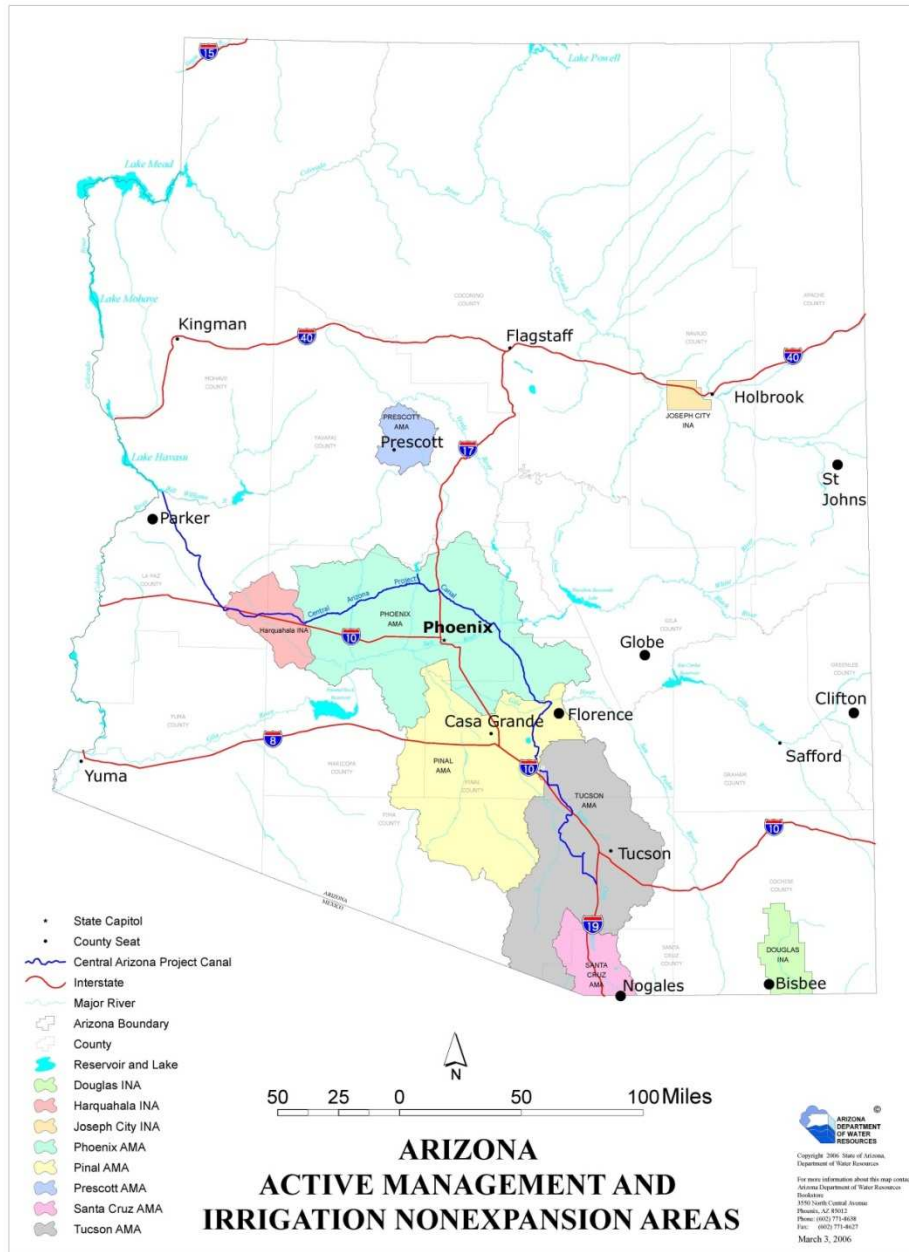


Figure 10 Arizona Department of Water Resources Active Management Area Map

Source: Arizona Department of Water Resources



With continuing problems from the over allocation of water resources of the Colorado River, the U.S. Secretary of the Interior issued water shortage guidelines for how all the water rights of the river will be managed in a time of shortage in 2007 (U.S. Bureau of Reclamation 2007) A trigger point was established on Lake Mead and water levels below this level trigger proportional reductions by all of the Colorado River basin states. This is the result of a river that has been over allocated and has reached what Peter Gleick terms “peak water” limit of the river capacity to balance the river flow and the use of this resource (Gleick 2011)

### **3.7 Sustainable Water Management for Southwest Cities**

With growing concerns on the availability and supply of water for future growth of the southwest, cities are forced to take a long hard look on how they are managing their available water sources. The two main sources of water for the southwest; the Colorado and Rio Grande Rivers are over allocated and are in periods of moderate to severe drought due to climate variability in the region. Access to new sources of water will be limited in the future, as the cost and availability of water will be hard to acquire. The challenge for southwest cities is to establish policies and procedures for water management that maximizes the efficiency and minimize waste of their available water resources (Malloy 2013).

Sources of water for each of the growing Southwest cities has prompted a need to find increasingly larger water reserves as population growth sharply

increased the demand for water delivery to the new developments in the urbanized areas. Without assured water supply, the future of any of these cities will be in doubt. Local area decisions on water management and planning have played a significant role in the effectiveness of securing these water resources for the growth of the city. However, regional hydrologic patterns, geography, and climatic factors govern the sustainability of the locality. This section will describe the water portfolios of the major southwest cities and how they have incorporated sustainable practices into their water management plans.

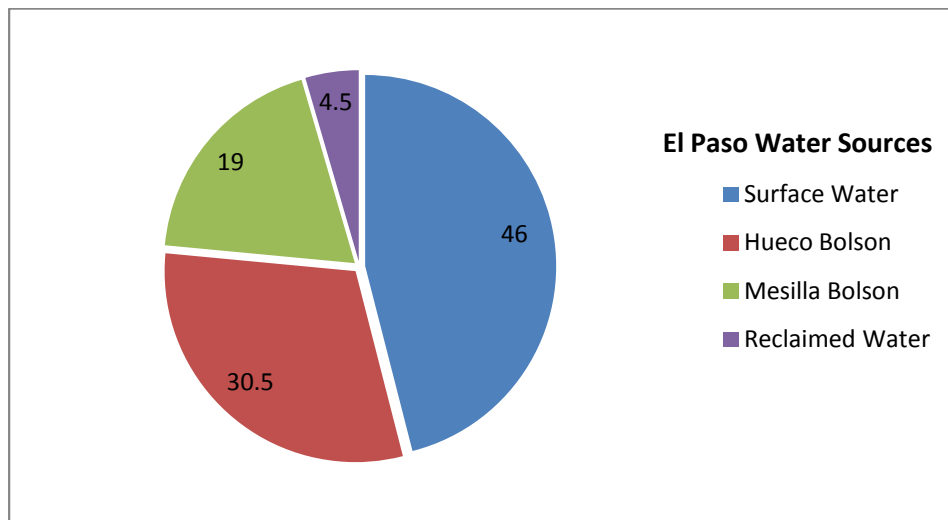
### **3.7.1 El Paso Area**

El Paso has relied on water from the Rio Grande and groundwater pumping as the primary water sources. El Paso shares water withdrawals from the Hueco and Mesilla *bolsons* (aquifers) with the City of Juarez, Mexico. The longevity of the underground aquifer is tied to the hydrologic cycle of the Rio Grande River. With the current rate of water mining from the watershed, a serious problem is on the horizon for the region. El Paso city water managers are attempting to address the problem through the development of new water resources, recovery, and reuse of treated wastewater and aggressive conservation programs. By the 1990s, the Hueco Bolson aquifer was losing three feet annually, which created an urgent need for the El Paso Water Utilities (EPWU) to find new sources of water.

Water supply for the El Paso region relies on surface water from the Rio Grande River and pumping of groundwater. The total volume of water available is

131,000 Acre feet per year of which 60,000 comes from surface water, 40,000 from the Hueco Bolson aquifer, 25,000 from the Mesilla Bolson aquifer, and 6,000 from reclaimed water (Figure 11). The continued drop in the groundwater tables of the region and reduced river flows on the Rio Grande River required El Paso to adopt more creative solutions to develop alternative sources of water for future development.

El Paso Water Utilities (EPWU) responded to this situation by purchasing 202 acres of land near the base of the Franklin Mountains to collect and manage storm runoff. El Paso also owns 100,000 acres of farmland that can be a source of water transfer to the urban area for future water supplies (Figure 12). In addition, EPWU entered into an agreement with the Department of Defense to construct on the largest inland water desalination plants capable of producing 27.5 million gallons of water a day (Scott 2012). The 87 million dollar plant captures previously unusable brackish water from the aquifer and turns it into potable drinking water for urban uses.



## Figure 11 El Paso Water Resources

Source: El Paso Water Utilities

El Paso wastewater treatment plants generate 6,000 acre feet annually of effluent that is used in area golf courses, parks, schools, cooling water towers. The Northwest plant processes 17.7 MGD, the Bustamonte plant 39 MGD, and the Fred Harvey plant 10 MGD of municipal wastewater. A future project proposes processing the irrigation water with reverse osmosis to return pure water, which will be blended with groundwater to improve water quality. The Dell City project proposes to transfer 10,000 acre feet of water annually to El Paso by 2050 and 20,000 by 2060. El Paso must purchase additional property, install groundwater wells, and construct a pipeline (Scott 2012).

On the demand side, El Paso has adopted a conservation plan to promote water conservation for EPWU customers. The utility uses progressive water rate structure to discourage indiscriminant use of water. The rate is based on the percentage of water use over the annual winter average for the customer. The City enacted water ordinance with mandatory restrictions on water usage. This ordinance regulates which days a resident can water outside landscape and restricts the hours of irrigation to before 10 AM or after 6 PM. Car washing is allowed only with the use of a bucket and a hose with a shutoff valve. Fines for noncompliance range from 50 to 500 dollars. Incentives under the conservation program include rebates of \$1 per square foot for removing turf grass, free low flow shower heads,

and rebates for low flow toilets and front loading washing machines. The results of El Paso's conservation program have reduced residential water use from 200 GPCD in 1990 to 140 GPCD in 2009 (El Paso Water Utilities 2007).

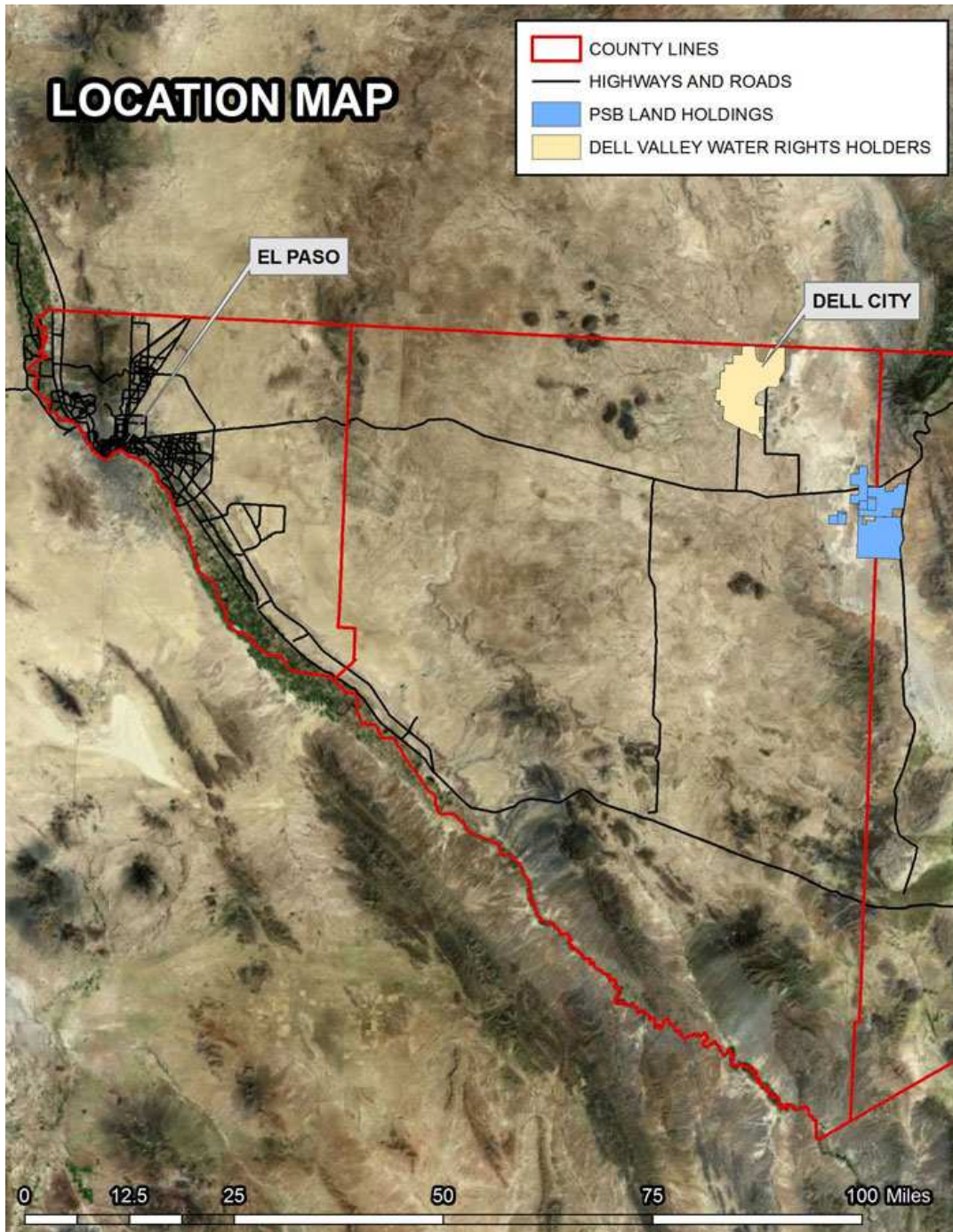


Figure 12 El Paso Water Reserves

Source: El Paso Water Utilities

### **3.7.2 Albuquerque**

The city of Albuquerque primarily had relied on ground and surface water reserves for the municipal water supply from the Middle Rio Grande watershed. This aquifer is derived from deep basin fill deposits about 14,000 feet in depth; only 2,000 feet of this constitutes the aquifer system. The aquifer is an enclosed basin region surrounded by the Sandia, Manzanita, Los Pinos and Jemez mountains. Currently, the Middle Rio Grande aquifer is in danger of depletion due to excessive groundwater pumping. The Rio Grande River is now experiencing extreme periods of low or no flow during the dry season.

The region was thought to have an inexhaustible supply of water for the foreseeable future (Kelly 1982). As urban development and population growth progressed, problems with depletion of groundwater tables, land subsidence, and diminished replenishment of the aquifer precipitated the need to develop a long-term strategy for sustainable water management for the future. In the 1960's, the Bureau of Reclamation established the San Juan-Chama, a water diversion project to bring much needed water to the growing New Mexico region (Figure 13). The City of Albuquerque was awarded about 48,000 acre feet per year from the diversion project. The water was channeled through 26 miles of tunnels, across the Continental Divide, and into the El Vado and Abiquiu reservoirs. The traditional water plan called for the use of groundwater pumping with the release of San Juan-Chama water from the reservoirs to enhance the groundwater uptake. The project, completed in 2008, allowed New Mexico to gain direct access to its Colorado River

allotment and thus lessen the region's reliance on groundwater pumping as the principal source of water for urban development.

ABCWA established a pilot project to recharge water to the aquifer in Bear Canyon Arroyo. Preliminary results indicate the project was successful in recharging the aquifer and a future expansion of the recharge project is being contemplated. The North I-25 Reclamation/Reuse project was constructed to take refuse water from the chip manufacturing plant and use it for landscape and turf irrigation at the Balloon Fiesta Park. The Southside Water Reclamation Plant provides effluent water for industrial and turf uses in the South Valley (Stomp 2004).

In 1995, an ordinance was passed in Albuquerque that prohibited water from running to the street on residential or commercial properties. Additionally, the ordinance banned outside watering during peak daylight hours. A rebate program was setup to promote voluntary cooperation with water conservation efforts. Some of the rebates offered include (1) 25% off the cost of a multi-function sprinkler controller (2) 25% off the cost of renting equipment to remove turf grass (3) \$25-100 rebate for the purchase of cisterns for rainwater harvesting (4) 20 credit on the water bill for attending the Authority's irrigation efficiency class (5) rebates for evaporative cooler thermostats, hot water recirculation systems, showerheads, and high efficiency washing machines (6) xeriscape rebates of \$1.00 per square foot of landscape renovated with approved xeriscape plants and materials (Albuquerque Bernalillo Water Authority 2013

).



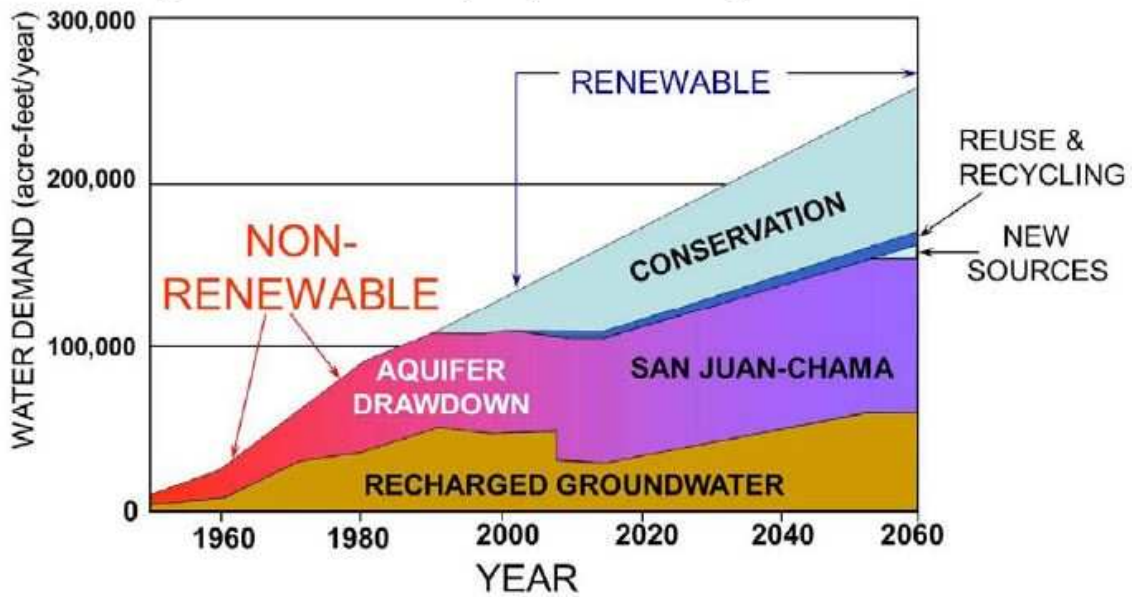
# San Juan Chama Drinking Water Project



Figure 13 San Juan Chama Map

Source: Albuquerque Bernalillo County Water Authority

Urban development in Albuquerque and the surrounding cities has been rescued from impending disaster by the San Juan Chama project that has reduced the area’s reliance on groundwater as the sole source of water for development. Future projections by ABCWA anticipates an increasing reliance on groundwater and surface water sources, but an increasing role of conservation, reclamation, and new sources of water for the future (Figure 14).



**Conservation** – water savings from historic use  
**Reuse & Recycling** – non-potable reuse from North I-25 and Southside Reuse projects  
**San Juan-Chama** – transition to SJC water under the Drinking Water Project  
**Aquifer Drawdown** – drawdown due to use of aquifer storage  
**Renewable Groundwater** – aquifer recharge from natural sources primarily the Rio Grande  
**New Sources** – future sources of supply to maintain sustainable usage

Figure 14 Future Water Sources Projections for Albuquerque, New Mexico

Source: Albuquerque Bernalillo County Water Authority

### **3.7.3 Las Vegas**

Las Vegas relies primarily on withdrawal of surface water from Lake Mead and recycling of municipal wastewater to support the city's water portfolio (Figure 15). Early settlements in the allocation of Colorado River water left Nevada with a paltry sum of water in relation to the already developed neighboring states of California and Arizona. At the time of the Colorado River Compact Nevada was a desolate state with little hope of supporting a significant urban population and was only allocated an annual withdrawal allowance of 300,000 acre feet, compare to Arizona's 2.8 million and California's 4.4 million acre feet. Today, the demographic of the Southwest have shifted to a point where Nevada is now is one of the fastest growing urban population in the region. Additionally, the natural rainfall of the region is the lowest of any of the desert cities, thus limiting the ability of sustained reliance on groundwater resources. Nevada has put forth a decade old plan to allow the state to withdraw more water from Lake Mead. Nevada argues that it has the surface water rights to 128,000 acre feet from the Muddy and Virgin Rivers. The state feels that it has the right to recapture the water from the reservoir instead of building expensive pipelines to transport the water within the state. California and Arizona strongly object to this plan and the decision will have to be made in Washington. In a recent agreement, Arizona will allow water starved Nevada to take

as much as 1.25 million acre feet of Arizona’s Colorado River allotment in exchange for about \$330 million dollars (McKinnon 2004).

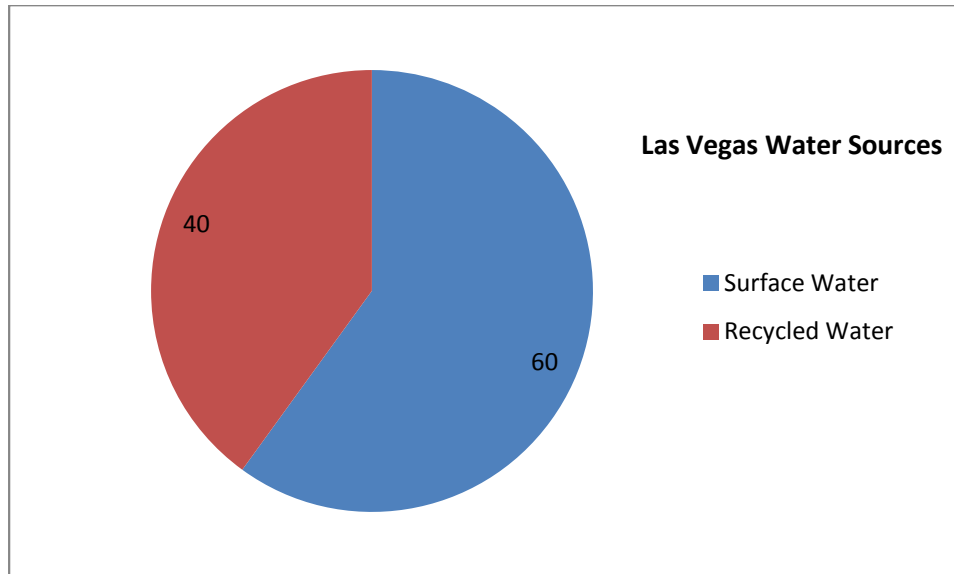


Figure 15 Las Vegas Water Resources

Source:(Southern Nevada Water Authority 2009a)

In 1947, the Las Vegas Valley Water District (LVVWD) was formed to provide water service to the greater Las Vegas region. As the area developed, the concerns for water security for southern Nevada cities with the new understanding that a regional approach to water management might present a more sustainable approach to water management for all of the entities. In 1991, the Southern Nevada Water Authority (SNWA) was forming with the alliance of the City of Boulder City, City of Henderson, City of Las Vegas, City of North Las Vegas, Clark County Water Reclamation District, and the Las Vegas Valley Water District (Figure 16). This collaborative agreement allowed for more effective planning and use of existing

water infrastructure between the participating entities to meet the future water demands of the growing urban population.



Figure 16 Southern Nevada Water Authority (SNWA) Infrastructure Map

Source: Southern Nevada Water Authority

On a large scale, Nevada has an uphill battle to find additional water resources to add to its water portfolio to support current and future needs for development. Solutions to augment Nevada’s water supply have involved the funding of water conservation projects in exchange for water supply and controversial proposals to construct pipelines from outside the state and region to deliver water. The concept of “Intentionally Created Surplus (ICS)” water was forged from the 2007 Interim Agreement with the Secretary of the Interior on Colorado River Shortage Guidelines that provided means for water credits to any

participating State that funds conservation projects that save water anywhere in the Colorado River system (U.S. Bureau of Reclamation 2007). Nevada has taken advantage of this within its jurisdiction with the funding of the Virgin/Muddy Rivers Tributary Conservation ICS and the Coyote Springs Groundwater Imported ICS which feed up “new” water for consumptive use. In addition, Nevada and other Colorado river basin states has provided funding for the construction of the Drop 2 reservoir along the lower Colorado River to retain water that might otherwise be lost and sent downstream without beneficial use. Nevada has also been exploring the possibility of entering an agreement with California or Mexico to construct a large-scale desalination plant in the ocean. A project of this type would provide locally produced water from seawater and usable water credits for Nevada from a transfer of Colorado River allotments.

Nevada has entered into agreements with the Arizona Water Banking Authority and the Metropolitan Water Conservation District of Southern California to bank water for future use. The principal of water banking is that a governing agency has the ability to store water underground, which can be withdrawn in the future for consumptive use. The agreements with California and Arizona will allow Nevada to withdraw water directly from Lake Mead as this resource is needed.

Las Vegas and the Greater Southern Nevada region have been recycling wastewater for over 50 years and have adopted recycling as part of a strategic water resource plan for over 20 years. SNWA wastewater treatment plants have the capacity to process 250 MGD of municipal wastewater (Figure 17). Las

Vegas is one of 7% of municipalities in the U.S. that use advanced tertiary treatment of wastewater that includes biological treatment, nutrient removal, chemical treatment, filtering, and removal of chemical additives. Recycled water is used for golf course irrigation, return flow to the Colorado River, dust control, water cooling towers, indirect potable water reuse, parks and schools, and car wash operations.

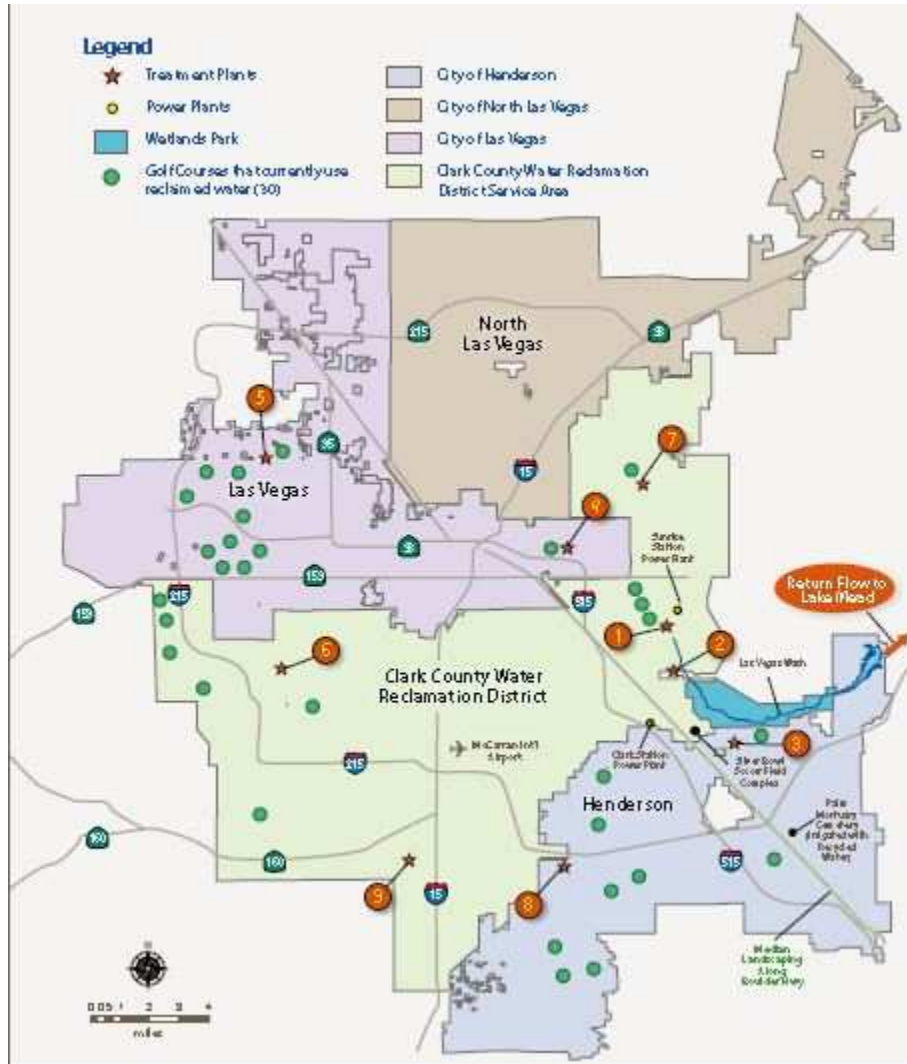


Figure 17 SNWA Water Treatment Facilities Map

Source: (Southern Nevada Water Authority 2009a)

On the demand side, SNWA has adopted a water conservation program to promote the conservation of water resources within the district. In 1991, Las Vegas adopted an ordinance to restrict water usage in periods of drought. Later in 2003, a more stringent policy was adopted to include mandatory restrictions on water use, installation of lawns, and washing of cars. It was initially a temporary measure, but later adopted as permanent with the involvement of a citizen advisory group. The Water Smart Landscape Rebate Program provides a rebate of \$1.50 per square foot of turf removed up to 5,000 square feet and \$1 beyond that amount. The program has removed over 130 million square feet of turf, which provides a substantial saving of water that was previously used to sustain the lawns. The Water Efficient Technologies Program provides up to \$150,000 for businesses that install new technologies that can save at least 500,000 gallons per year. A rebate is also available for the purchase of a “smart” irrigation controller for residential customers. SNWA has a designated Water Smart Contractor and Water Smart Home branding for those companies and homes that meet their criteria for knowledge and materials to promote water conservation (Southern Nevada Water Authority 2009b).

Future supply planning for the Southern Nevada region will rely on finding or augmenting water supply through measures such as intentionally created surplus or water tight agreements, increased conservation and public outreach in demand conservation, and increases in water recycling and recovery from the regional wastewater treatment plants (Figure 18).



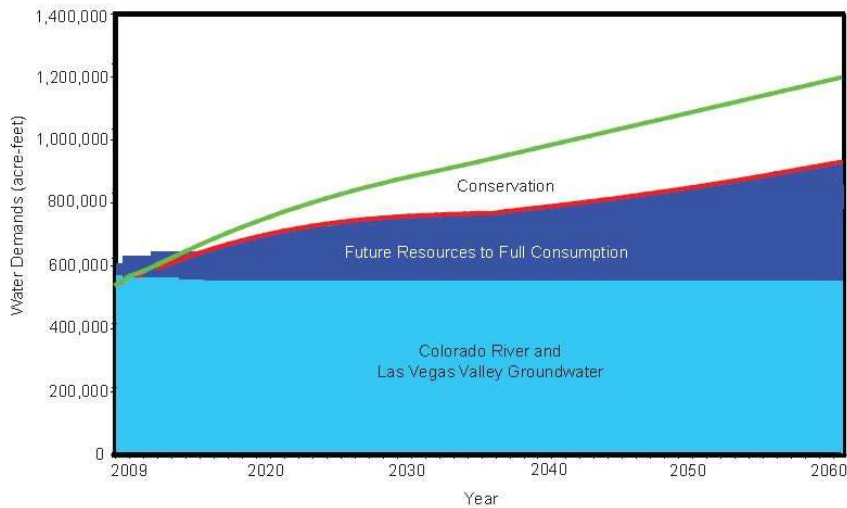


Figure 18 Las Vegas Future Projections for Water Demand

Source: (Southern Nevada Water Authority 2009b)

### 3.7.4 Phoenix

Phoenix has been blessed with having the ability to draw on several sources of water to accommodate growth. The Salt River Project that was established in 1911 has provided a continuous supply of water to the cities by the canals system. In addition, many independent water providers in the region use or augment their water supply through groundwater pumping. The construction of the Central Arizona Project has added an additional source of water from the Colorado River. As a result, Phoenix has benefited from being at a unique geographical position in the hydrologic regime. The current water portfolio for the city includes water from the

Central Arizona Project Canal (44%), Salt River Project Canal (50%), reclaimed water (3%), and groundwater (3%) (Figure 19). The City of Phoenix was granted a “Designation of Assured Water Supply” until 2025 by the Arizona Department of Water Resources. Under the Arizona Groundwater Management Act, this designation is a requirement for the city to continue new development projects within its administrative boundaries (City of Phoenix 2011).

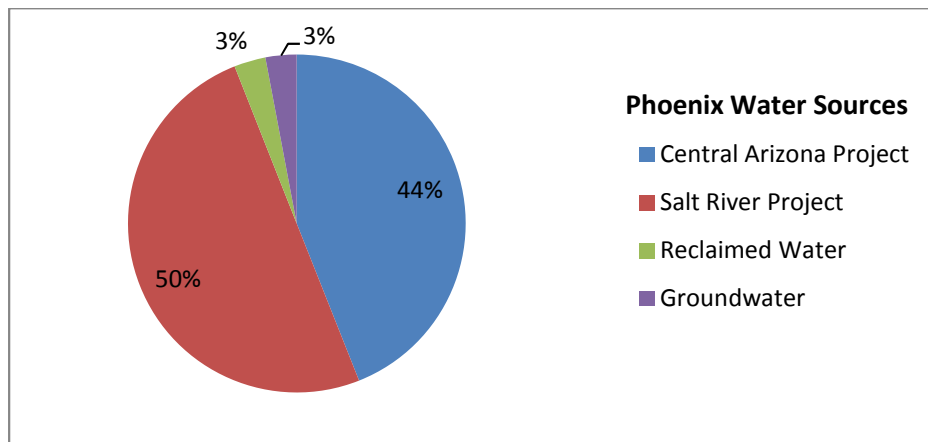


Figure 19 City of Phoenix Water Sources

Source: (City of Phoenix 2011)

Phoenix has divided their water planning efforts in designations of “on project” area, those that were part of the original agreement with the Federal government for the financing of the Roosevelt dam project, and “off project” areas, those expanded service areas outside the SRP boundaries. The categories of “nonmember areas” and “water rights areas” designate other smaller areas not included in the early agreements on Salt River Project waters. “Gateway waters” are those waters given credit to the city by its financing of the spillway gates on the

Horseshoe Dam and modifications to the Roosevelt Dam, which was then able to retain more water for future use.

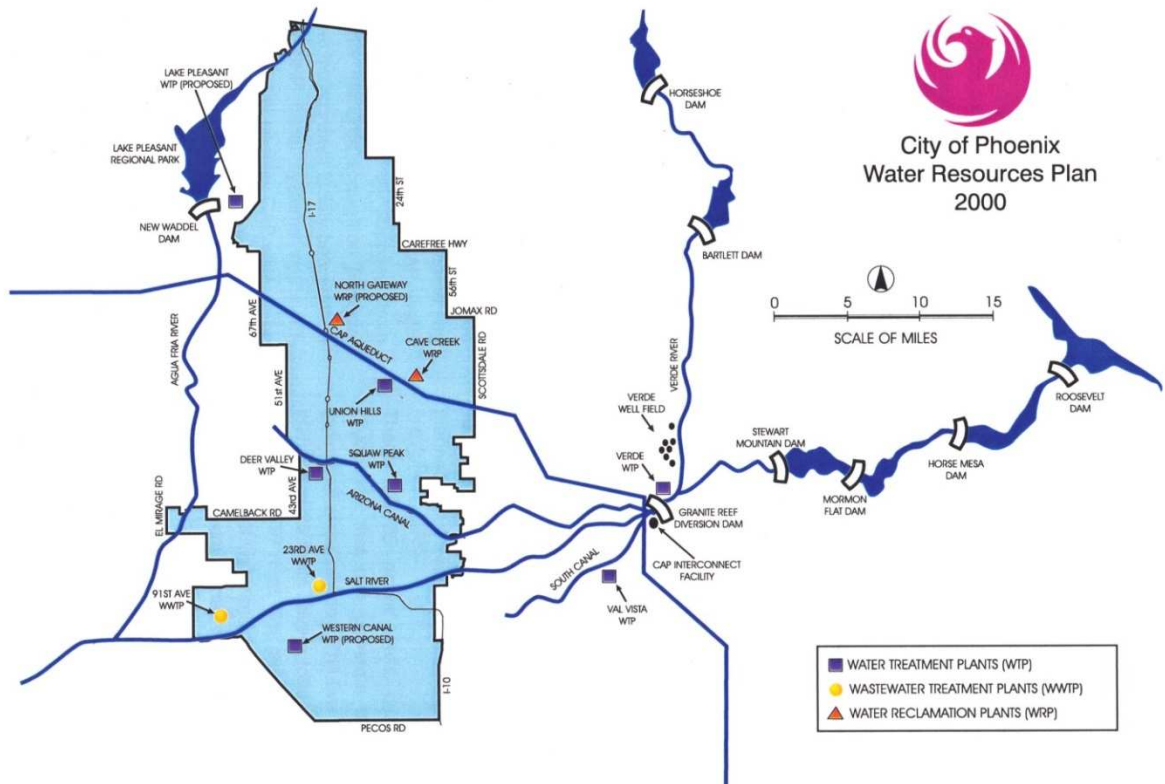


Figure 20 City of Phoenix Water Treatment Plants Map

Source: (City of Phoenix 2000)

The City established its first water treatment plant on the Verde River with a capacity of 50 million gallons per day (MGPD) in 1947, after the quality of the groundwater in the areas necessitated the need for a better quality potable water source. From 1952-1975, the City constructed three more water treatment plants: 24<sup>th</sup> St. (140 MGPD), Deer Valley (150 MGPD), and Val Vista (130 MGPD), a joint

project with the City of Mesa to provide water for the urbanized areas of the City (Figure 18). In 1990, an interconnection facility was constructed at the Granite Reef Dam to allow for seamless water transfers between the CAP and SRP canal systems. The Lake Pleasant Water Treatment Plant (80 MGD) was put online in 2007 to serve North Phoenix. Additionally, the City maintains 20 active groundwater wells with a capacity of 28 MGD.

Water reclamation is one of the principal means for retaining and reusing water within the urbanized areas. The City of Phoenix retains about 40% of the water used in municipal for wastewater treatment plants. Of this, 90% is used in non-potable reuse applications as treated effluent. The largest facility is a sub-regional facility operated by a group of municipalities at the 91<sup>st</sup>. Avenue Wastewater Treatment Plant. Upon treatment, the plant delivers the output water to the Buckeye Irrigation Company, where it is used for agricultural uses. The plant also supplies by pipeline the Arizona Public Service's Palo Verde Nuclear Generating Station west of Phoenix with cooling water for the nuclear reactor. In North Phoenix, the City generates 2 MGD of reclaimed water at the Cave Creek Water Treatment Plant that is used for golf courses and other industrial uses in the area.

A special agreement between SRP and the Roosevelt Irrigation District (RID) allowed for the direct delivery of 30,000 AF of treated wastewater from the City from the 23<sup>rd</sup>. Ave WWTP to be transferred to RID, which supplies this water to farmers for agricultural use. RID, in exchange, supplies SRP with an equivalent amount of groundwater to be sent by SRP canals back to Phoenix. This agreement

was part of a settlement with the Salt River Pima Maricopa Indian Community (SRPMIC) to settle prior water right disputes with the tribe. SRPMIC gets 10,000 AF of this water delivered to them by SRP.

The Tres Rios Habitat Restoration Project is a six mile artificial wetland project that was constructed west of the 91<sup>st</sup>. Ave WWTP. The goal of the project was to create a natural tertiary water treatment process using riparian vegetation to act as a filter to clean the water to drinking water standards. This project has proven to be successful, and has provided scenic and recreational value through the establishment of this aquatic habitat. Tres Rios has processed approximately 20,000 AF of wastewater per year. Another habitat restoration project called Rio Oeste is planned for the future, but is waiting funding from the U.S. Army Corps of Engineers.

To enhance the supply side of the water problem, the City has sought out multiple options for future water needs for development. In 1986, the City purchased 14,000 acres of farm land west of Phoenix in the McMullen Valley. This land is being used for agricultural production, but is slated to be retired and the water pumped and transported to Phoenix to serve the City's future water needs.

The City of Phoenix Water Resources Plan concludes that the City is well situated to meet the anticipated water demands for growth through 2050 (Figure 21). Since Phoenix is uniquely located to capture multiple sources of water from the Salt River Project, Central Arizona Project, groundwater, and reclaimed water, it has the ability to continue growth with its current water resource portfolio (City of Phoenix 2011). The question for Phoenix going forward is how to effectively manage

the resources they have including existing water rights and the acquisition of new water resources through infrastructure, conservation, or purchase of water rights.

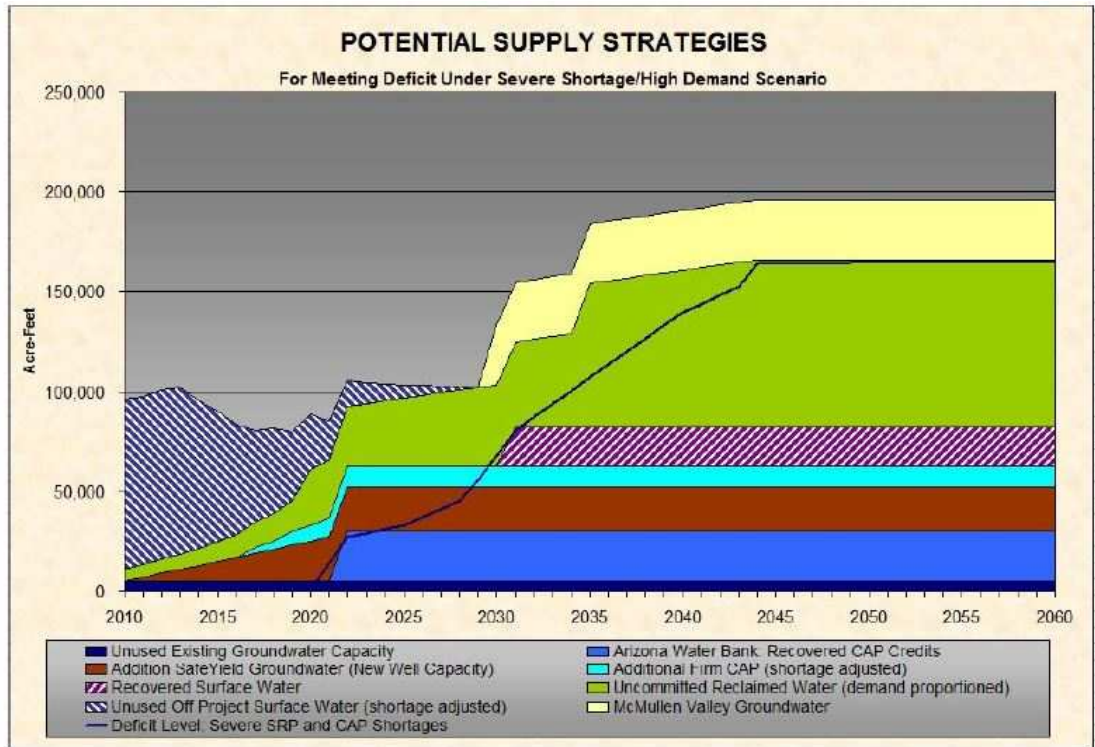


Figure 21 City of Phoenix Future Projections for Water Sources

Source: (City of Phoenix 2011)

### 3.7.5 Tucson

Until the early 1990's, Tucson relied on groundwater as the only source for growth and development. Early efforts to develop water banking and storage projects in the Tucson area suffered a major defeat from public support in paying for these large scale projects. As a result, Tucson has been forced to rely on

groundwater pumping as the primary source of water for the city. Tucson Water Company established wells along the Valencia Road south of the city as the main supply source. The growing need for urban water motivated the city to begin purchasing land in the Avra Valley region to serve as water farms to be piped into the Tucson Valley. In addition, Tucson began purchasing water companies outside the city limits so that it could begin a basin-wide management strategy for water resources.

Tucson has struggled with water issues and public support for infrastructure development. While the city of Tucson was able to add numerous wells from new water sources along the Old Nogales Highway in 1954 and 1968, the result of this water mining caused a massive die off of the extensive Mesquite bosques by the lowering of the groundwater table in the area around the San Xavier del Bac mission (University of Arizona 1998). Additionally, the historic depletion of the groundwater table in the Tucson aquifer resulted in significant land subsidence fissures due to the groundwater pumping. The lower water table required redrilling of some wells and increased cost to pump the water to the surface.

In 1990, the CAP canal was completed to Tucson, this providing the long anticipated relief from the water deficit problems of the region. Problems soon arose from the use of CAP water for residential use. Colorado River water is harder and contains a larger share of total dissolved solids than local groundwater. More importantly, CAP water began causing corrosion problems in the residential water infrastructure. After angry protests from area residents, Tucson Water backed off

the direct use of CAP water in the potable water system. In 1995, Tucson voters approved the Water Consumer Protection Act that restricted the use of CAP for residential use, unless it conformed to the local water quality standards. The water supply situation in Tucson is still a critical issue. Long-term groundwater pumping is causing areas of land subsidence and area wells are going dry quickly. As Tucson grapples with the challenge of finding ways to best manage its water resources, growth and development will continue to deplete the existing water resources of the city. Efforts to conserve water through a tiered water rate structure, public education and awareness on water conservation, and regulations requiring the harvesting of rainwater for new developments, among others are strategies adopted to help reduce water use by its residents (City of Tucson 2004).

To address the concerns on water quality by Tucson residents, Tucson Water constructed CAVSARP, a large-scale water reclamation facility in Avra Valley (Figure 22). The facility opened in 2001 on a 330 acre site that included 27 wells, 54 MGD booster station, 8 million gallon reservoir, and 25 miles of connecting pipeline. Current plans include the expansion of the facility to accommodate more recharge and the construction of SAVSARP facility to the south and the Three Points Well Field facility. Under consideration is the possible addition of enhanced water filtration equipment at the water treatment plant using reverse osmosis to further purify and blend Colorado River water with the native water from the Tucson basin.



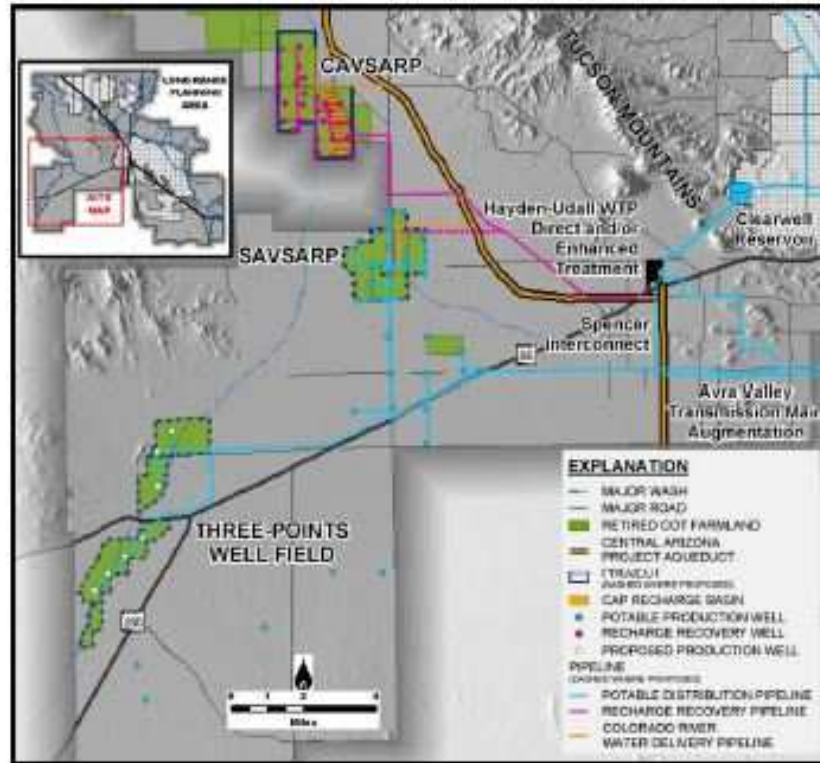


Figure 22 Tucson Water Facilities

Source: (City of Tucson 2004)

Tucson has been aggressive in trying to capture and reuse water within its jurisdiction. The Tucson wastewater treatment plants produce 30,739 acre feet of effluent per year. Of this, 13,121 acre feet were captured and used as reclaimed water and the remainder was discharged to the Santa Cruz River. Plans are under consideration to increase the available effluent to 63,000 acre feet by 2030 (City of Tucson 2004).

Planning for the future growth in Tucson will require careful planning and management of the water resources (Figure 23). Water banking will be a key part of the strategy for safeguarding Tucson’s Colorado River allotment, as well as the

completion of additional storage and recharge facilities. To retain its Assured Water Supply designation by the Arizona Department of Water Resources, Tucson will need to augment its water sources somehow or increase its conservation efforts by reducing customer demands for water. The future scenario envisions both an increase in supply and increased conservation through demand management and increases in reclaimed water.

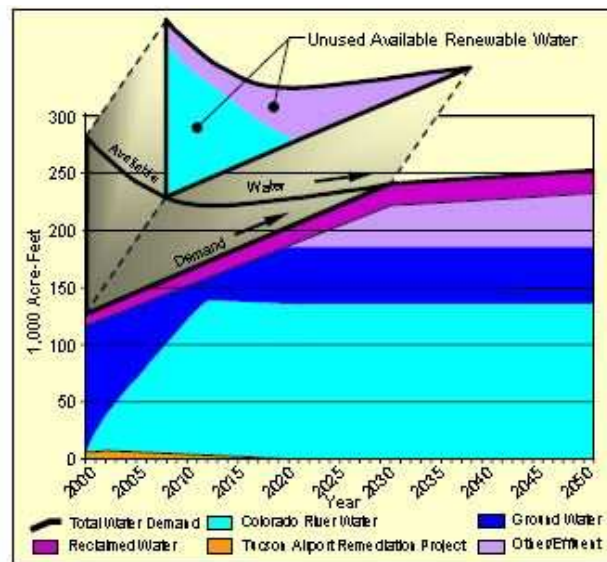


Figure 23 Tucson Projected Water Demands 2000-2050

Source: (City of Tucson 2004)

#### 4. Conclusion

The Southwest has an appeal of character and uniqueness that sets it apart from other regions of the country. The history of these towns from the days of cowboys and Indians left a mark on the establishment of these emerging sunbelt cities. The rapidly urbanizing desert cities are attracting new residents seeking

prosperity and enjoyment from these urban settings. The fragile balance of the region could easily be lost without an understanding of how these great cities developed. The scarcity of water will define the region and dictate the places where development can occur. Las Vegas and Tucson are in the most critical position to contemplate the future of the urban area with imminently diminishing water reserves for development. We hope that the people of today will carry forth responsible development that will continue to serve the existing community and maintain a viable city to live, work and play.

In the end, the Southwest cities will continue to grow and develop in the United States. Southwest cities have an abundance of sunshine and seasonable weather that has been a force of attraction for people from other areas to consider relocation or investments. Area leaders have shown leadership in attempting to attract relatively clean industries that would provide high-paying jobs and community development projects. The quality of life through economic diversity and stability is an attractive element of the Southwest urban centers.

The increase in population and diversity has come at the cost of creating more urban pollution and congestion from industrial and transportation activities. The quality of air that was once an attractive quality in these desert cities is now an area of health concern. The current pace of development will continue to add to the mounting problems in the region. In addition, areas that have refrained from comprehensive solutions to critical community problems will suffer the consequences by limiting the development of the urban center. Tucson, for

example, is now experiencing critical concerns for urban development due to the lack of availability of long-term water resources to support development activities.

Urban sprawl is creating an aesthetically unappealing landscape of disjunct houses and developments and human activities. The effect of private development that favors low density urban planning has created strains on municipal infrastructure and urban transportation systems. Also, the conversion of the natural desert in some areas around the rapidly urbanizing cities creates new challenges for Southwest cities to meet anticipated water demands for urban development projects for a sustainable future.

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